

The effect of CO_2 pricing on conventional and non-conventional oil supply and demand

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■ *Green paradox*

A carbon tax rising at the rate of interest would depress the pre-tax price of fuel by the amount of the tax (Sinn, 2008).

→ the post-tax price is unchanged

→ countries outside of an international agreement benefit from cheaper oil and increase consumption and emissions, *climate change accelerates*.

This depends on the carbon intensity of the backstop (Newbery, 2011), (van der Ploeg and Withagen, 2010).

■ *Question*

What is the effect of a CO_2 tax on oil supply and demand?

Does a CO_2 tax depress the pre-tax price of oil? By how much?

This paper quantifies the effect of a CO_2 tax in the case of a CO_2 -intensive backstop (synthetic crude oil).

■ *Methodology*

Interaction between conventional oil and CO_2 intensive backstop (synthetic crude oil) under CO_2 pricing

Cost: The model takes into account: depletion, experience, social cost of CO_2 .

Price: Price net of extraction costs rises at the rate of interest (Hotelling, 1931):

$$\lambda_t = \lambda_{t_0} \cdot e^{r \cdot (t - t_0)}$$

This rule is modified with **stock effects** (Heal, 1976), (Levhari & Liviatan, 1977).
(The orders of magnitude are such that this does not change the results)

Subjective probability: a probability value or distribution determined by an individual's best estimate based on personal knowledge, expertise, and experience.

Model: Interaction between conventional and non-conventional oil

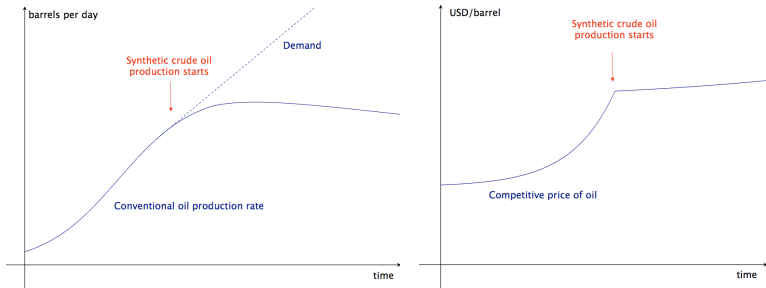
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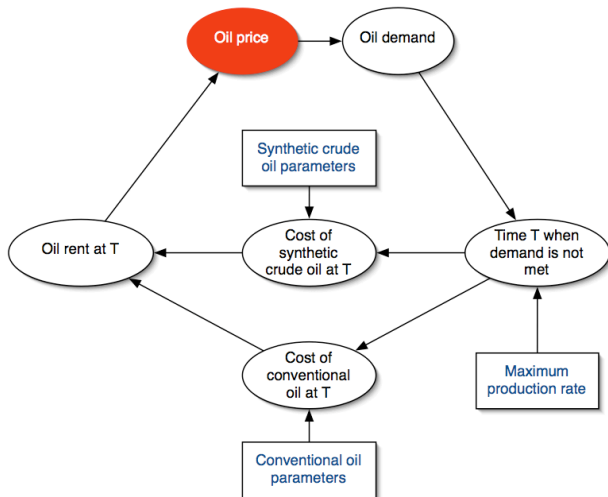
T = time when conventional oil production is unable to meet demand

Price of oil at T = initial cost of producing synthetic crude oil

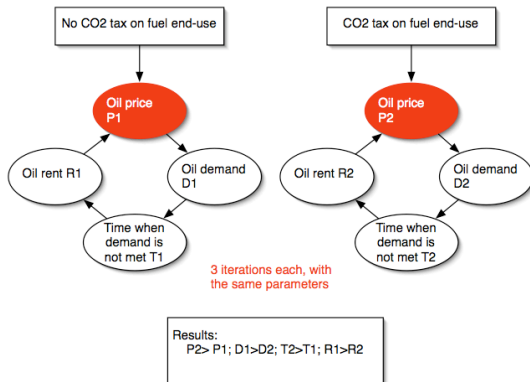
Model assumptions

- Synthetic crude oil is a substitute of conventional oil. It is treated as a backstop.
- At the beginning of the period, only conventional oil supplies the market. The price is determined by the Hotelling rule.
- Synthetic crude oil production starts when conventional oil production is unable to meet demand
- At that time T , the price of oil is set at the initial cost of producing synthetic crude oil
- The social cost of CO_2 is included in the calculations

Model structure



Model structure



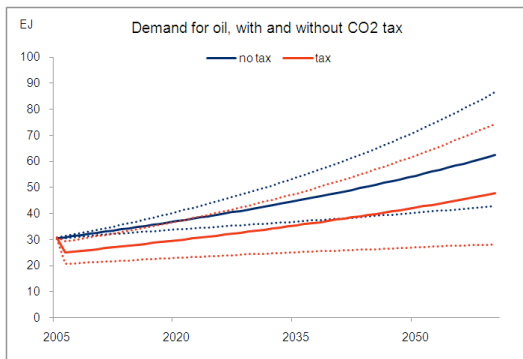
CO₂ tax → higher price → lower demand → later T → lower rent → lower price → higher demand, etc.

As the model converges one effect takes over, leading to either higher or lower demand and extraction.

Main model parameters

Cost of oil: function of cumulative production (experience, depletion)

- *The social cost of CO₂*
Initial cost of CO₂ (26, 100, 322) USD/tCO₂
Social cost of CO₂ growth rate (2.0, 2.5, 3.0) % per year
- *Production and demand (conventional oil)*
Maximum production rate (90, 101, 121) million barrels per day
Price elasticity of demand (-0.6, -0.3, 0.0) no unit
Income elasticity of demand (0.4, 0.9, 1.4) no unit
- *Cost of synthetic crude oil from Canadian in-situ bitumen*
Initial cost of SCO (without CO₂) (41, 47, 52) USD/barrel
Initial emissions (0.09, 0.16, 0.23) tCO₂/barrel SCO
Cost of synthetic crude oil at T: (45, 100, 156) USD/barrel
- *Discounting*
Consumption discount rate (0.9, 2.6, 4.2) % per year



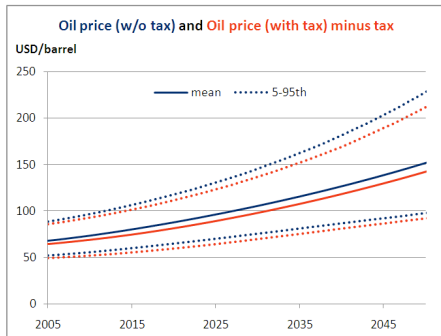
Full line: mean - Dotted lines: 5th and 95th percentiles

A tax on CO₂ from fuel use would reduce demand and extraction, despite the effect of the reduced oil rent.

Results: is there a Green paradox?

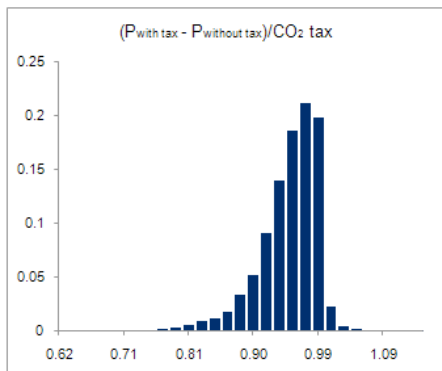
W/o an int'l agreement on CO_2 : all countries see $P_{w/o\ tax}$

With an int'l agreement on CO_2 :
inside countries see $P_{post\ tax}$
outside countries see $P_{pre\ tax}$
 $P_{pre\ tax} = P_{post\ tax} - CO_2\ tax$



$P_{pre\ tax}$ is not far below $P_{w/o\ tax}$: the effect seems rather limited

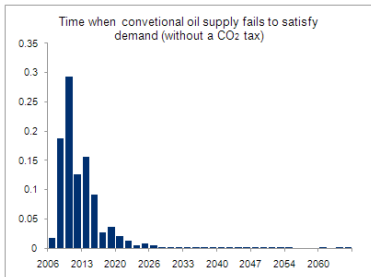
Results: CO_2 tax carried into the final oil price



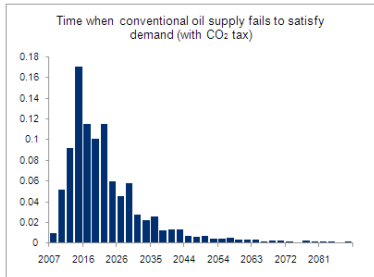
Between 87 and 99% of the CO_2 tax is carried into the oil price.

Countries that remain outside an international agreement would benefit from oil prices 1% to 13% lower than without the tax.

Results: Time T with and without a CO_2 tax



Without a CO_2 tax on fuel use
T between 2008 and 2021
(mean value: 2013)



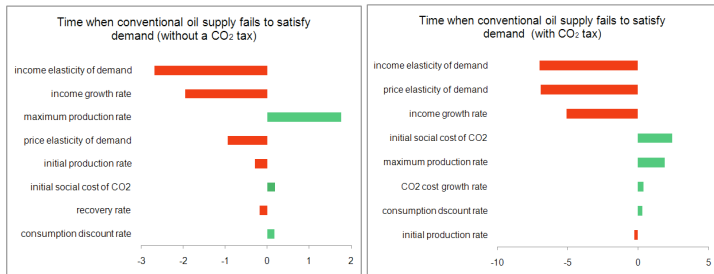
With a CO_2 tax on fuel use
T between 2011 and 2050
(mean value: 2024)

UKERC (2009): Peak oil between 2009 and 2031

Shell (2008): Easy oil and gas fails to match demand by 2015

Influences on T with and without a CO₂ tax

Influences show the change of T (years) when a parameter is increased by one standard deviation.



Large influence of the price elasticity of demand and the demand growth rate parameters, with and without a CO₂ tax on fuel use.

With a CO₂ tax:

- a reduction of 0.20 units of the income elasticity would delay T by 7 years.
- an increase of 0.12 unit of the price elasticity would delay T by 7 years.

- Between 87% and 99% of a CO_2 tax would be carried into the final oil price.
- Oil prices seen by countries outside of an international agreement would be 1 to 13% lower than without the tax.
- A CO_2 tax enforced worldwide would still reduce oil demand and production, hence CO_2 emissions from oil production and use.
- A CO_2 tax on fuel use would delay T by about 11 years (mean value)
- T is very sensitive to the price elasticity of demand and the income elasticity of demand: great potential of demand-side measures to smooth the transition to low-carbon liquid fuel alternatives.

References

Devarajan, S., Fisher, A.C., 1981. Hotelling's "Economics of Exhaustible Resources": Fifty Years Later. *Journal of Economic Literature* 19 (1) 65-73.

Heal, G., 1976. The Relationship between Price and Extraction Cost for a Resource with a Backstop Technology. *The Bell Journal of Economics* 7 (2) 371-378.

Hotelling, H., 1931. The Economics of Exhaustible Resources. *The Journal of Political Economy* 39 (2) 137-175.

Levhari, D., Liviatan, N., 1977. Notes on Hotelling's Economics of Exhaustible Resources. *The Canadian Journal of Economics* 10 (2) 177-192.

Newbery, D., 2011. Oil shortages, climate change and collective action. *Phil. Trans. R. Soc. A* 369 1748-1761.

Shell, 2008. Shell Energy Scenarios to 2050.

Sinn, H.W., 2008. Public policies against global warming. *International Tax and Public Finance* 15 (4) 360-394.

UKERC, 2009. Global Oil Depletion - An assessment of the evidence for a near-term peak in global oil production.

van der Ploeg, F., Withagen, C., 2010. Is there really a Green Paradox? CESIFO Working Paper 2963.

Thank you!



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au service du développement durable

Parameters' ranges (1/2)

Parameter	Minimum	Most likely	Maximum	Std dev.	Unit
CO₂ cost					
Initial CO ₂ costs (C_{CO_2,t_0})	26	100	322	64	USD/tCO ₂
CO ₂ costs growth rate (α)	0.02	0.025	0.03	0.00	per year
Non-conventional oil initial cost					
Upgrading efficiency (Y_U)	0.78	0.82	0.86	0.02	no unit
Initial in-situ costs (C_{IS,t_0})	17.0	18.5	20.0	2.9	USD/barrel
Initial upgrading costs (C_{U,t_0})	22.0	25.0	27.0	1.0	USD/barrel
Non-conventional oil emissions					
In-situ initial emissions (e_{IS,t_0})	0.049	0.082	0.115	0.02	tCO _{2e} /barrel
Upgrading initial emissions (e_{U,t_0})	0.038	0.064	0.090	0.010	tCO _{2e} /barrel*
Conventional oil resources					
Resources in place (Q_{conv})	7.0E+12	7.5E+12	8.0E+12	2.0E+11	barrels
Recovery rate (R_{conv})	0.35	0.43	0.50	0.04	no unit
Conventional oil demand					
Income growth rate (g)	2.0	3.0	5.0	0.6	% per year
Initial demand (d_{t_0})	3.00E+10	3.05E+10	3.10E+10	2.04E+08	barrels/year
Price elasticity of demand (pe)	-0.6	-0.3	0	0.12	no unit
Income elasticity of demand (ie)	0.4	0.9	1.4	0.2	no unit
Conventional oil production					
Maximum production rate ($x_{conv,max}$)	3.32E+10	3.67E+10	4.02E+10	1.42E+09	barrels/year
Decline rate ($\alpha_{decline}$)	0.0	2.0	4.0	0.008	% per year
Initial cumulative production (X_{conv,t_0})	1.0E+12	1.0E+12	1.0E+12	0.0E+12	barrels

Parameters' ranges (2/2)

Conventional oil costs and learning					
Maximum depletion costs ($C_{max,conv}$)	86	104	121	7.14	USD/barrel
Depletion exponent (γ)	1.04	2.50	4.00	0.60	no unit
Initial costs (C_{conv,t_0})	34	39	44	2.04	USD/barrel
Learning rate (LR_{conv})	0.04	0.05	0.06	0.004	no unit
Minimum costs ($C_{conv,min}$)	10	20	30	4.1	USD/barrel
Conventional oil emissions					
Initial emissions (e_{conv,t_0})	0.022	0.026	0.029	0.0014	tCO _{2c} /barrel
Other					
Consumption discount rate (r)	0.9	2.6	4.2	0.7	%/year

* barrel SCO